

## Divertor design through shape optimization

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The power and particle exhaust problem for next step fusion reactors is a daunting one. A large fraction of the fusion power has to be extracted from the reactor through the divertor, while power loads to plasma facing components should not exceed limits imposed by the materials in order to prevent excessive erosion and melting. At the same time sufficient pumping capability for the Helium ash has to be ensured. The development of divertors which can safely handle this power and particle exhaust is critical for the successful operation of future fusion power plants.

The exhaust processes in the divertor are governed by a set of complex physical interactions between plasma, neutrals and the surface. It is therefore not surprising that divertor design for next step reactors strongly relies on numerical simulations, using code packages such as a.o. B2-EIRENE [1]. Due to the expensive nature of these simulations, combined with the large number of design variables, divertor design could greatly benefit from more automated design procedures.

In view of the considerations given above, we reformulate the divertor design problem as a shape optimization problem. Design requirements, e.g. a homogeneous power load on the divertor targets, are incorporated in a cost functional which measures the performance of a certain design. By means of changes in the shape of the divertor, which in turn lead to changes in the plasma state, this cost functional can be minimized. Using the adjoint method [2], derivatives of the cost functional with respect to the shape of the divertor can be computed very efficiently. The divertor design which minimizes the cost functional is then found by applying gradient based optimization algorithms.

Recasting the design problem in an optimization framework has important advantages. First of all, the optimization program automatically selects the optimal design for a certain cost functional, avoiding the need to simulate a large number of candidate designs. Secondly, using advanced adjoint techniques, the computational cost for a complete design cycle equals only a few times the cost for the numerical evaluation of a single design. Finally, physics, material and engineering constraints can naturally be accounted for in the optimization algorithm.

In the paper, the optimization approach to divertor design is illustrated using a strongly simplified 2D plasma fluid model. Transport equations are solved for a single ion species (D). Parallel transport is classical, radial transport anomalous. Perfect temperature equilibration between ions and electrons is assumed. Neutrals are modeled with a purely diffusive 2D fluid model. With this model, we optimize the shape of the divertor targets in order to obtain the highest target power load spreading as possible.

In future work, the methodology will be adapted to more advanced plasma and neutral models, and different cost functionals or design requirements, e.g. optimal pumping capacity, maximum SOL power throughput subject to material constraints, etc.

[1] D. Reiter, M. Baelmans, P. Börner, Fusion Sci Tech **47** (2005) 172–186

[2] A. Jameson, L. Martinelli, N.A. Pierce, Theor Comput Fluid Dynam **10** (1998) 213-237